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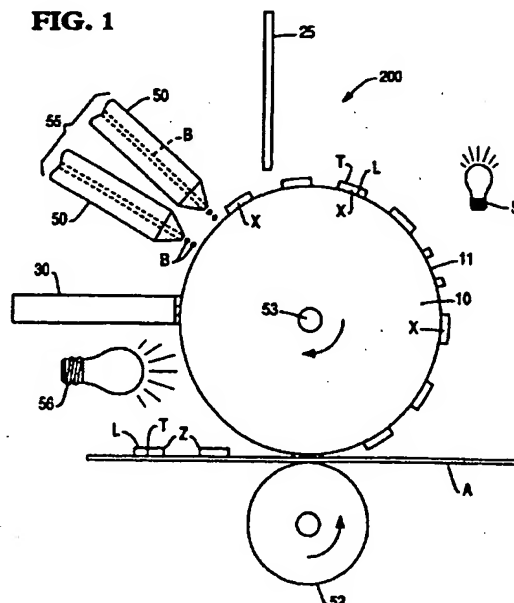
INT CL<sup>6</sup> B41J 2/17 2/435 2/44, B41M 7/00

(54) Abstract Title

**Two-stage transfer printing method using radiant energy curable ink**

(57) The method involves depositing an image X on a roller 10 using a curable ink B ejected from inkjet printheads 50. The image has an upper surface T and lower surface L so that as the roller rotates the upper surface of the image is exposed to a first radiant energy source 51 (e.g. UV light) to partially cure the image. The exposed image is then transferred to a receiving substrate A so that the upper and lower surfaces of the image are reversed in forming a transferred image Z on the substrate. A second radiant energy source 56 completes the curing of the image Z. The roller may be preheated (31, Fig. 2), wherein only one radiant energy source is used to completely cure the image X. The roller can be replaced by a continuous belt or ribbon and the inkjet printheads by a thermal transfer printhead (Fig. 4). Alternatively, the two types of printheads can be used in combination with a belt (Fig. 5).

**FIG. 1**



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**FIG. 1**

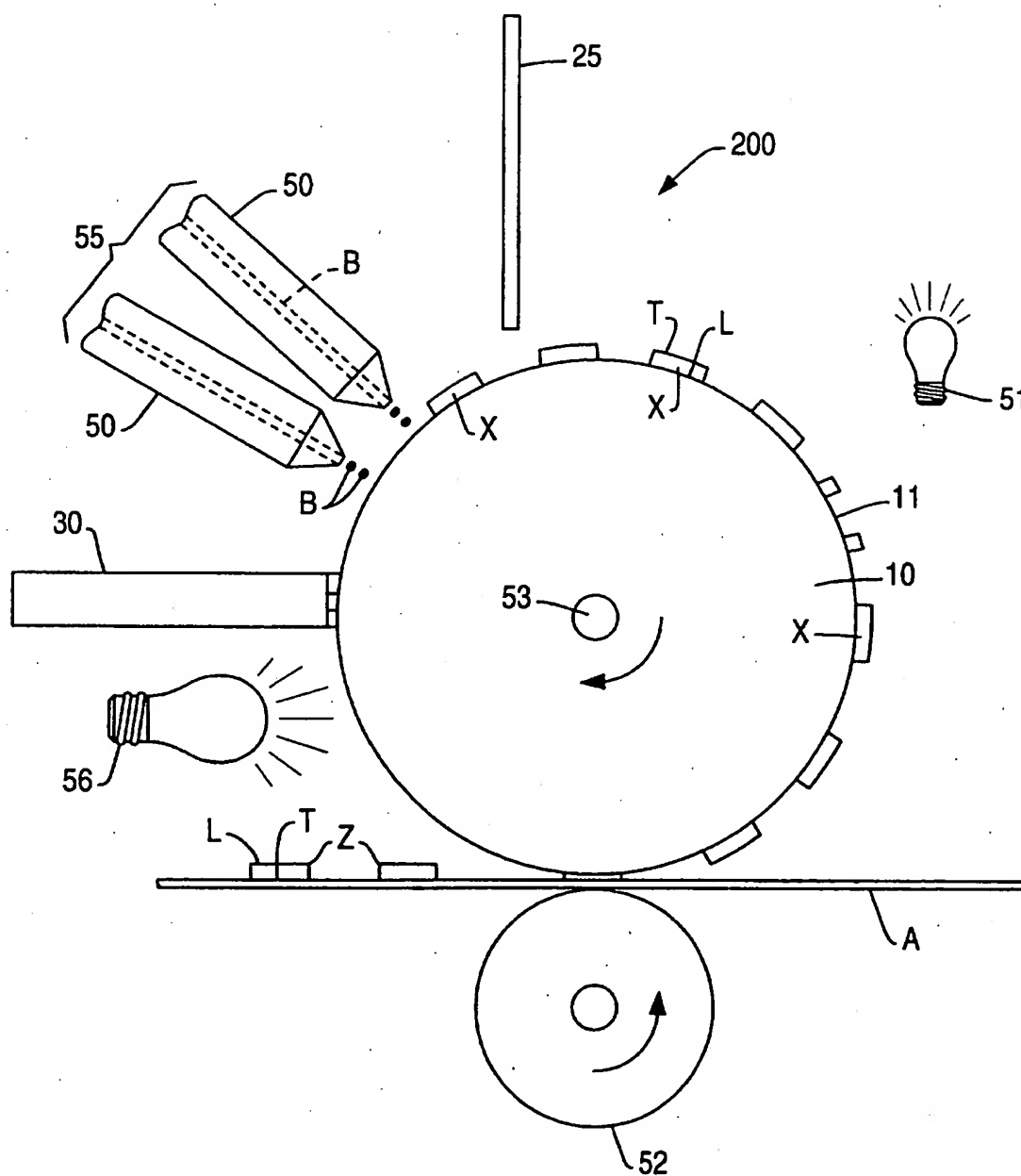
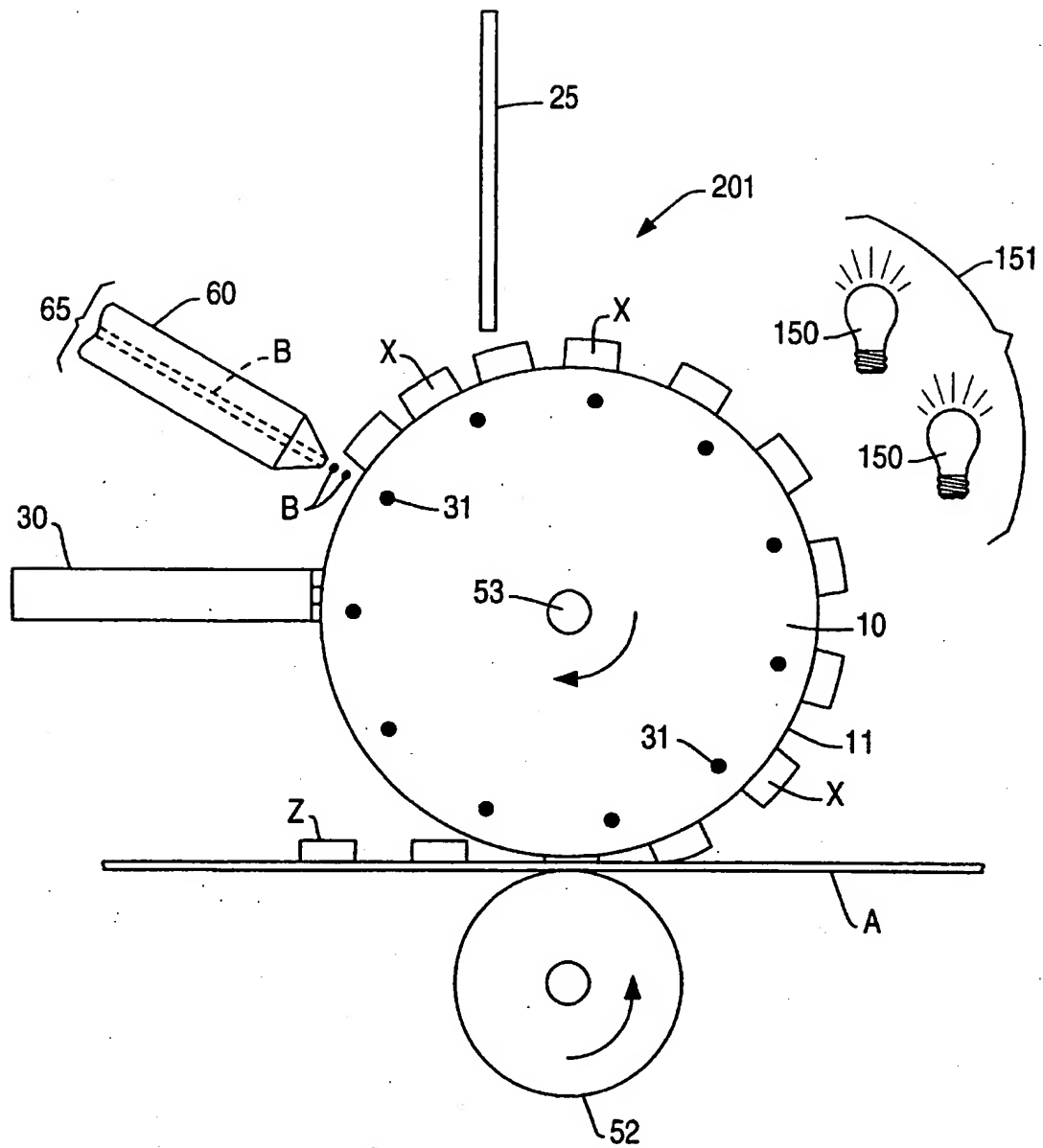
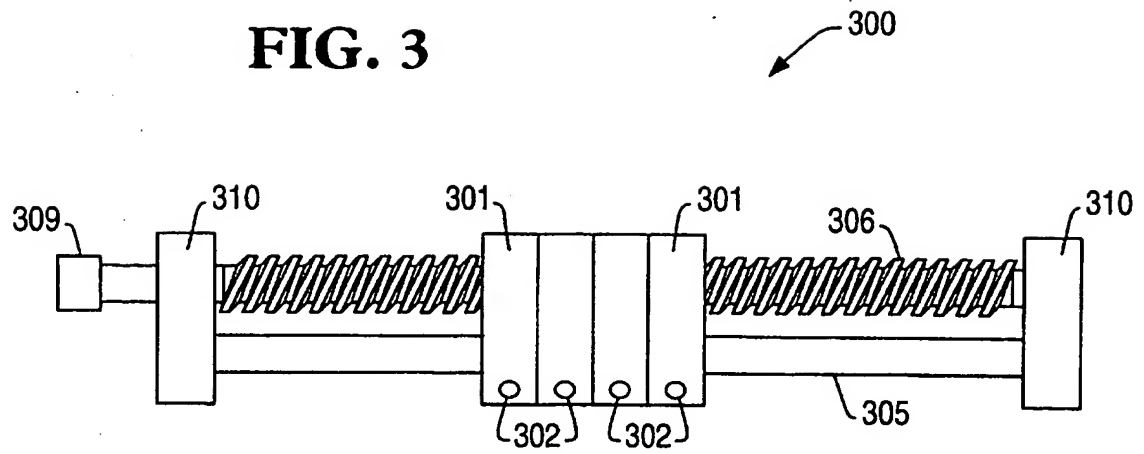


FIG. 2



**FIG. 3**



**FIG. 6**

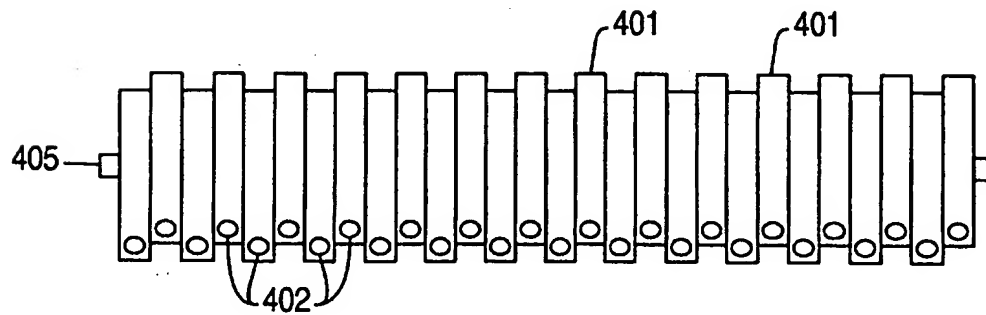
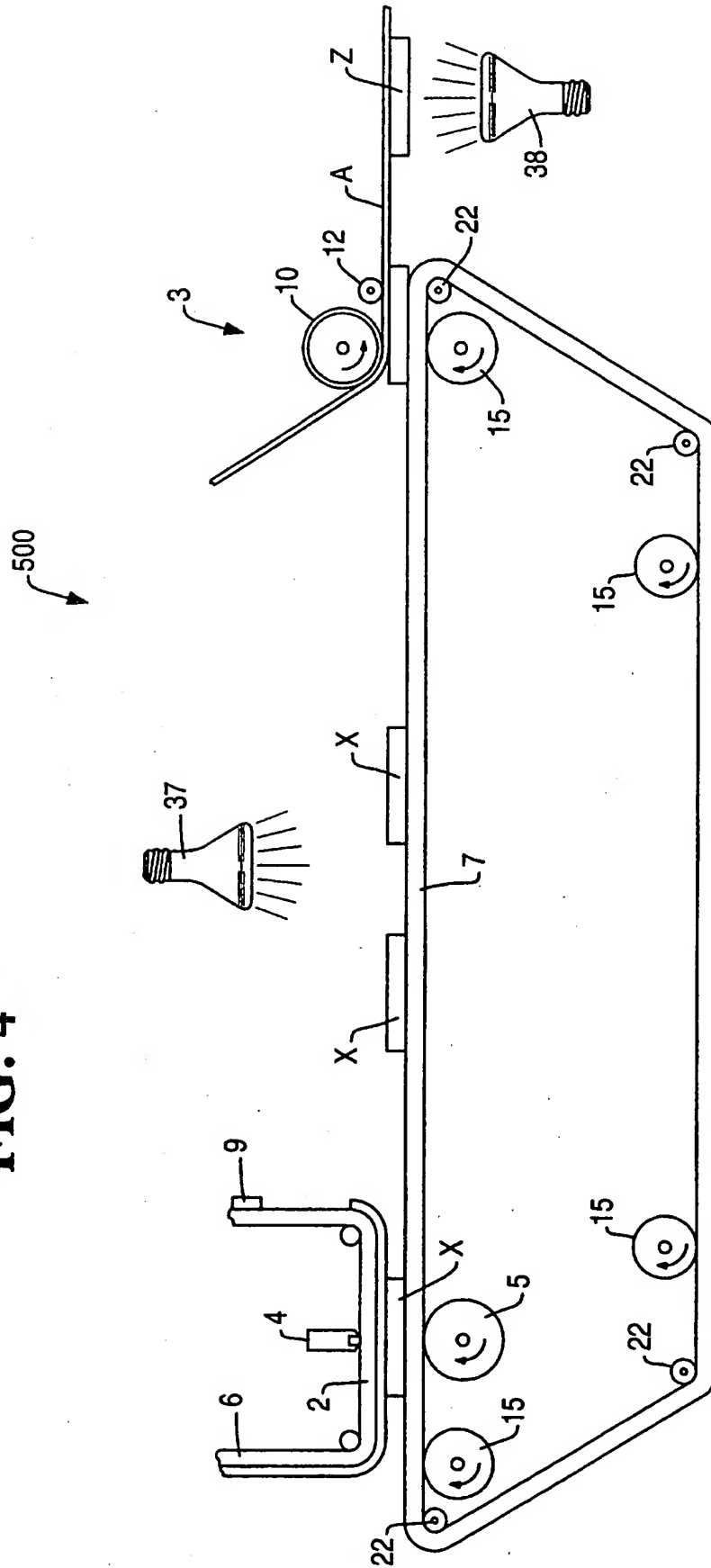
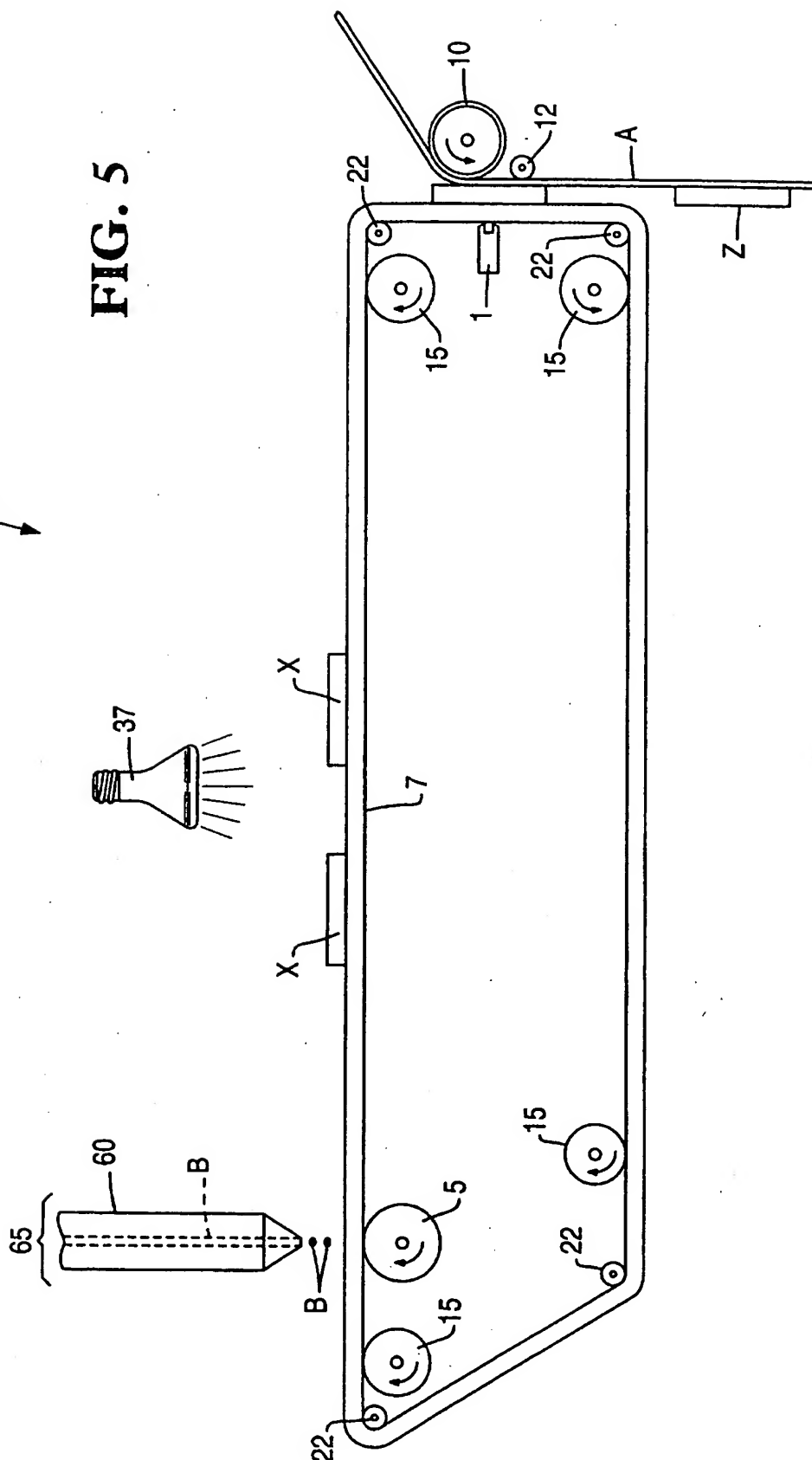


FIG. 4



501

FIG. 5



METHOD AND APPARATUS FOR PRINTING  
USING RADIANT ENERGY CURABLE INK

The invention relates to printing methods and apparatus which employ inks curable  
5 by radiant energy. The methods and apparatus are adaptable for use with ink jet print heads  
and thermal transfer print heads.

In conventional printing processes and apparatus which employ inks curable by  
radiant energy, particularly those which employ ink jet print heads and thermal transfer print  
heads, it is difficult for light or other radiant energy to penetrate colored ink layers. The  
10 pigments and dyes block or absorb the radiant energy, reducing the energy available to  
initiate the polymerization and often resulting in surface cure. The degree of cure decreases  
with increasing depth within the ink layer. It is desirable to provide a method and apparatus  
which will more thoroughly cure radiation curable inks with such pigments and dyes.

Ink jet printers are likely to find increased use as the technology is advanced due to  
15 high print speeds and economy of operation. Typical ink jet printers operate by employing  
a plurality of actuator elements to expel droplets of ink through an associated plurality of  
nozzles. A typical print head actuator is described in U.S. Patent 4,516,140. Each actuator  
element is typically located in a chamber filled with ink supplied from a reservoir. Each  
actuator element is associated with a nozzle that defines part of the chamber. On energizing  
20 a particular actuator element, a droplet of ink is expelled through the nozzle toward the print  
medium either by pressure or vaporization. Those wherein the ink is drawn through the  
nozzle by an electrostatic field are also known. In most configurations, the print head  
containing the nozzles is moved repeatedly across the width of the print medium on guide  
rails. After each movement, the print medium is advanced to the width of the swath for the  
25 next pass of the pen. In some configurations, such as in high volume printers, the print  
head extends across the full width of the print medium. At a designated number of  
increments, each of the nozzles are caused to either eject ink or refrain from ejecting ink.  
The movement over the medium can print a swath approximately as wide as the number of  
nozzles arranged in the column.

30 These conventional ink jet printing methods and apparatus have limitations. Such  
printing methods often suffer in definition and quality and, in some cases, print speed due to

the low viscosity required of the ink employed. Low viscosity values for the ink are required to enable ejection from the print head. This often necessitates high solvent content. The high solvent content requires that the ink be drawn into the print medium to enable rapid drying. When such inks are drawn into the print media, the edges tend to become less defined. Inks of different colors may bleed into each other when drawn into the absorptive print media. Where the print media has a low absorption rate for the ink, such as transparency film, the ink tends to clump together due to surface tension. In addition, print speed is reduced since the ink takes a longer time to dry on the non-absorptive substrate. Another problem which may be encountered in ink jet printing is paper cockle, wherein the print media swells once the ink is absorbed, causing the paper to warp (cockle). It is desirable to provide an ink jet printing method and apparatus wherein the print quality and print speed do not suffer from the high solvent content of the ink.

In thermal transfer printing, images are formed on a receiving substrate by heating extremely precise areas of a print ribbon with thin film resistors. This heating of the localized area causes transfer of ink or other sensible material from the ribbon to the receiving substrate. The sensible material is typically a pigment or dye. These techniques provide images with higher definition and quality than ink jet methods in that high viscosity inks are used which need not wick into the receiving medium. Print speed is not delayed by wicking of the ink. However, UV curable inks and visible light curable inks suffer from surface cure because of limits on penetration of radiant energy.

It is an object of the present invention to provide an improved method and apparatus for printing using radiant energy curable ink.

According to a first aspect of the present invention, there is provided a method of printing, characterized by the steps of:

- a) depositing ink in the form of an image on a surface of an intermediate substrate from an ink source, the ink being curable by radiant energy and the ink image having an upper surface and lower surface;
- b) exposing at least the upper surface of the ink image on the intermediate substrate to radiant energy to at least partially cure the ink image; and
- c) transferring the exposed ink image on the intermediate substrate to a receiving substrate such that the upper surface and the lower surface of the ink image are



reversed in forming a transferred ink image on the receiving substrate. The transferred ink image on the receiving substrate may then be exposed to radiant energy to further cure the ink.

In one preferred embodiment, the ink may be deposited on the intermediate substrate by an ink jet print head, although use of other printing techniques, such as thermal transfer printing, are also suitable. The radiant energy is preferably ultraviolet light, although visible light or infrared radiation may also be used. In curing the ink both before and after transfer to the receiving substrate, both sides of the ink can be cured, allowing greater penetration of radiation and elimination of single surface cure.

In an alternative embodiment, the ink image formed on the surface of the intermediate substrate is heated to a temperature above the ambient temperature and the transferred image is cooled to ambient temperature. Exposure of the transferred ink image on the receiving substrate to radiation is then optional.

According to another aspect of the present invention, there is provided an apparatus for printing images on a receiving substrate comprising:

- a) a print head adapted to form images on a substrate with an ink curable by exposure to radiant energy; characterized by
- b) an intermediate substrate positioned to receive ink images formed by the print head, on a surface thereof;
- c) an advancing means for moving the surface of the intermediate substrate which receives ink images relative to the print head;
- d) a radiant energy source positioned to expose the ink images on the surface of the intermediate substrate to radiant energy; and
- e) feeding means which is adapted to move the receiving substrate so that it contacts and overlaps the ink images on the intermediate substrate in such a manner that the ink image transfers to the receiving substrate.

A second radiant energy source may be provided to expose the transferred ink image to radiant energy, so as further cure the ink.

The print head may be an ink jet print head or a thermal transfer print head. In one embodiment, there is provided heating means for heating the ink image on the intermediate

substrate above ambient temperature. The use of a second radiant energy source to further cure the ink is then optional.

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:-

5 Fig. 1 is a schematic representation of an embodiment of a printer provided by this invention which employs a transfer roller as an intermediate substrate;

Fig. 2 is a schematic representation of another embodiment of a printer provided by the present invention which employs a transfer roller as an intermediate substrate;

10 Fig. 3 is a schematic representation of a carriage for an ink jet print head suitable for use in the present invention;

Fig. 4 is a schematic representation of an embodiment of a printer provided by the present invention which employs a continuous belt or ribbon as an intermediate substrate;

15 Fig. 5 is a schematic representation of another embodiment of a printer provided by the present invention which employs a continuous belt or ribbon as an intermediate substrate;

Fig. 6 is a schematic representation of a full width ink jet print head.

The present invention is directed to printing methods and printers and are independent of the means of forming an image, which are typically print heads. There is no particular restriction on the print head as long as it can form an image with radiant energy curable ink. Suitable print heads include ink jet print heads and thermal transfer print heads. Suitable ink jet print heads are those which actuate thermally, by a piezoelectric crystal or an electrostatic field. The embodiments described herein often refer to ink jet print heads; however, the invention is not limited thereto.

25 The printing processes and printers of the present invention employ a radiant energy cured ink and an intermediate substrate upon which an ink image is formed with the radiant energy curable ink. The use of the intermediate substrate provides many advantages, some of which include 1) a two-stage cure for the radiation curable ink, allowing both sides of the ink image to be exposed to radiant energy for a more complete and faster cure, and 2) a cure wherein wicking of the solvent does not occur on the final print medium.

30 Fig. 1 shows a Printer 200 of the present invention and illustrates in principle an example of a printing method of the present invention as well. Printer 200 employs two ink

jet print heads 50 as an image forming member 55. However, the printers and processes of the present invention include the use of a) single ink jet print heads, b) more than two ink jet print heads, c) thermal transfer print heads and other means for depositing ink as image forming members. The intermediate substrate employed in Printer 200 is transfer roller 10.

5 The ink jet print heads 50 form an ink image on transfer roller 10 by depositing ink B on surface 11. Surface 11 of transfer roller 10 is moved relative to the image forming member 55 to allow further deposition of ink B thereon. An advancing mechanism provides such relative motion. For Printer 200, pressure roller 52 serves as the advancing mechanism. Pressure roller 52 rotates transfer roller 10 about its axis 53 while moving receiving  
10 substrate A between pressure roller 52 and transfer roller 10. The advancing mechanism can vary widely in structure and includes a simple drive means for rotating transfer roller 10 about axis 53.

Radiant energy source 51 exposes ink images X on surface 11 of transfer roller 10. The ink images are at least partially cured from this exposure. The exposed ink image is  
15 then transferred to a receiving substrate A. This is accomplished by a feeding mechanism adapted to move receiving substrates so that they contact and overlap the ink images on the intermediate substrate. In Printer 200, pressure roller 52 serves as a feeding mechanism which moves receiving substrate A so that it contacts and overlaps ink images X on surface 11 of transfer roller 10. The pressure applied by roller 52 is such that the ink image X  
20 transfers to receiving substrate A to form ink image Z. The feeding mechanism can vary widely in structure and operation. Transfer of the exposed ink image X on the intermediate substrate to a receiving substrate reverses the top surface T and lower surface L of the ink image X in forming a transferred image Z. In Printer 200, a second radiant energy source 56 exposes the transferred ink images Z to radiant energy. The second radiant energy  
25 source is an optional feature in some embodiments of this invention where the radiant energy source 51 incompletely cures the ink image.

An embodiment of a printer which employs only one radiant energy source is shown in Fig. 2. Printer 201 comprises a single ink jet print head 60 as an image forming member 65 which deposits ink B on surface 11 of transfer roller 10. An advancing mechanism as  
30 used in Printer 200 of Fig. 1, is employed in Printer 201. Pressure roller 52 serves as an advancing mechanism in rotating transfer roller 10 so as to move surface 11 relative to ink

jet print head 60. Radiant energy source 151 via bulbs 150 exposes ink images X on the surface 11 of the transfer roller 10 to radiant energy and can completely cure ink image X. Printer 201 additionally contains a means for heating ink image X to a temperature above ambient temperature. Bulbs 150 also serve as a means for heating the ink images X to a temperature above ambient temperature. An alternative embodiment is to preheat transfer roller 10, which can be accomplished by thermal resistance heaters 31. These can be configured analogously to the transfer rollers used in conventional laser printers and photocopies which fuse dry toner. The exposed and heated ink image X is then transferred to a receiving substrate A by pressure roller 52 in a manner as described for Printer 200 of Fig. 1. The transferred ink image Z need not be exposed to a second radiant energy source if the ink is completely cured. However, the transferred ink image is allowed to cool to ambient temperature so as to harden and reduce tackiness.

To increase tackiness, the ink on the intermediate substrate may be heated in a number of ways such as by radiant energy source as in printer 201 of Fig. 2, by transferring heat from pressure roller 52, by resistance heaters or by hot air flows (not shown).

Combinations of devices can be used to heat the ink image. Such heating means may optionally be used with a printer having two radiant energy sources as in Printer 200 of Fig. 1.

Printers 200 and 201 each contain barrier 25. This barrier serves to isolate the image forming members 50 and 60 from radiant energy. Such a barrier is optional and may be superfluous depending upon the position of the radiant energy source and image forming member. Printers 200 and 201 also each contain an optional cleaning wand 30. The cleaning wand removes any residual ink which has not transferred to a receiving substrate from the intermediate substrate.

The radiant energy emitted by the radiant energy source is preferably ultraviolet light, visible light, infrared radiation or a combination thereof. The radiant energy source selected is dependent on the cure mechanism for the ink employed. Inks cured by ultraviolet light are common and such radiant energy sources are preferred.

The process and apparatus of this invention provides an advantage in that where curing with radiant energy is difficult to complete, the ink image can be exposed to radiant energy on both upper and lower surfaces due to their reversal upon transfer of the ink

images from the intermediate substrate to the receiving substrate. Inks can be easily formulated to be completely cured upon transfer to the receiving substrate. Inks may also be formulated to be completely cured in advance of transfer. Inks which are formulated to be completely cured by the single radiant energy source also benefit from the use of

5 intermediate substrate where deposited by an ink jet print head in that solvents required to aid in the deposition and formation of the ink image from such print heads are removed by heating the ink image; thereby reducing the impact such solvents have on image receiving substrates such as paper. Heating the ink image on the intermediate substrate also provides the opportunity to enhance the reaction kinetics. It is necessary to heat the completely cured

10 ink image to a temperature above ambient temperature to soften the ink image and enable transfer to a receiving substrate where it solidifies to a tack-free solid at room temperature.

As indicated previously, the image forming member that is employed in the printer of the present invention can vary widely in structure from ink jet print heads to thermal transfer print heads. Such print heads need not vary from conventional print heads.

15 Whether thermal, electrostatic or those activated by piezoelectric crystals, such print heads preferably have a plurality of nozzles to accommodate various colors. Thermal transfer print heads are less favored in that the inks deposited are solid at ambient temperature requiring the ink to be heated so as to allow for eventual transfer of the ink image from the intermediate substrate to a receiving substrate.

20 The image forming member may include guide rails or other mechanism which allows the print head to traverse the intermediate substrate surface in a direction perpendicular to movement of said advancing mechanism. Fig. 3 illustrates such an embodiment in image forming member 300, which comprises ink jet print head 301 with four nozzles 302. Print head 301 is mounted on guide rail 305 and drive screw 306 is

25 threaded through print head 301 so that print head 301 slides along guide rail 305 when drive screw 306 is turned clockwise or counterclockwise by driver 309. Frame members 310 support guide rail 305 and drive screw 306. The image forming member may comprise a print head which spans the full width of the transfer medium or a substantial portion thereof, as shown in Fig. 6, where image forming member 400 comprises print head 401

30 with multiple nozzles 402 mounted on rail 405.

The intermediate substrate is preferably a drum or roller as illustrated in Figs. 1 and 2. However, it is contemplated that the dimensions and configuration of intermediate substrate can vary significantly as needed. For example, the intermediate substrate can comprise individual plates, or a continuous belt or ribbon.

Fig. 4 illustrates an embodiment of this invention wherein the intermediate substrate is a continuous belt or ribbon. Fig. 4 illustrates a printer 500 of the present invention which employs a continuous belt 7 as an intermediate substrate. Thermal transfer print head 4 in combination with thermal transfer print ribbon 6 provides the image forming member 2. Ink 9 of ribbon 6 is transferred to continuous belt 7 in the form of an ink image X. The continuous belt 7 is moved relative to the image forming member 2 by a series of drive rollers 15 and guide rollers 22. Radiant energy source 37 radiates images X on the continuous belt 7. Feeding mechanism 3 moves receiving substrate A so that it contacts and overlaps ink image X on continuous belt 7 and transfers the ink image X to receiving substrate A. Feed mechanism 3 comprises drive roller 10 which feeds receiving substrate A to pressure roller 12 which presses receiving substrate A against the continuous belt 7 for transfer of ink image X. If desired, the transferred ink image Z on the receiving substrate is exposed to a second radiant energy source 38. Heat is applied to ink image X to enhance tackiness and improve transfer to receiving substrate A. In Printer 500, heat is applied to the ink image X through pressure roller 12 and by the radiant energy source 37.

An alternative embodiment is printer 501 shown in Fig. 5, which employs an ink jet print head 60 as the image forming member 65 and a thermal transfer print head 1. similar to print head 4 of Fig. 4, to heat the image X. Print head 1 transfers the ink image from continuous ribbon 7 to receiving substrate A, after exposure to radiant energy. It is obvious that the intermediate substrates do not need to be the belt itself, but can be planar or three-dimensional substrates, positioned on the belt. With such embodiments, inks can be applied to receiving substrates with three dimensional shapes such as bottles, jars and boxes.

The most common receiving substrate is paper sheets, including strip paper, art paper, colored paper and continuous rolls. However, the process and apparatus of the present invention are well suited for use with plastic sheets, plastic films, as well as three-dimensional objects, such as plastic bottles or cardboard boxes, as receiving substrates.

It is obvious that the advancing mechanism and feeding mechanism can vary widely in configuration and structure. Various drive means can be used to advance the intermediate substrates such as motors, pulleys, chains, pneumatic drives, etc. Various pressure rollers and feed configurations can be used to feed planar receiving substrates for transfer of the ink image. More complex assemblies are required for three dimensional receiving substrates such as bottles and boxes.

CLAIMS:

1. A method of printing, characterized by the steps of:
- 5 a) depositing ink in the form of an image (X) on a surface (11) of an intermediate substrate (10, 7) from an ink source (50, 60, 301, 401, 4), the ink being curable by radiant energy and the ink image (X) having an upper surface (T) and lower surface (L);
- b) exposing at least the upper surface (T) of the ink image (X) on the intermediate substrate (10, 7) to radiant energy to at least partially cure the ink image (X); and
- 10 c) transferring the exposed ink image (X) on the intermediate substrate (10, 7) to a receiving substrate (A) such that the upper surface (T) and the lower surface (L) of the ink image (X) are reversed in forming a transferred ink image (Z) on the receiving substrate (A).
- 15 2. A method according to claim 1, characterized by the step of exposing the upper surface (T) of the transferred ink image (Z) on the receiving substrate (A) to radiant energy to further cure the transferred ink image (Z).
- 20 3. A method according to claim 1, characterized in that the ink source is an ink jet print head (50, 60, 301, 401), the ink being deposited by ejection therefrom.
4. A method according to claim 1, characterized by the step of moving the surface (11) of the intermediate substrate (10, 7) upon which the ink image (X) is deposited prior to exposing the upper surface (T) of the ink image (X) on the intermediate substrate
- 25 (10, 7) to radiant energy.
5. A method according to claim 4, characterized in that the intermediate substrate is a transfer roller (10) which rotates to provide movement of the surface (11) thereof on which the ink image (X) is deposited relative to the ink source (50, 60, 301,
- 30 401).





6. A method according to claim 4, characterized in that the intermediate substrate is a belt (7) which rotates to provide movement of the surface (11) upon which the ink image (X) is deposited relative to the ink source.
- 5 7. A method according to claim 4, characterized in that the radiant energy is ultraviolet light, visible light, infrared radiation or combinations thereof.
8. A method according to claim 7, characterized by the steps of heating the ink image (X) on the intermediate substrate (10, 7) to a temperature above ambient temperature,  
10 and cooling the transferred ink image (Z) on the receiving substrate (A) to ambient temperature.
9. A method according to claim 8, characterized in that the ink image (X) on the intermediate substrate (10, 7) is heated to a temperature above ambient temperature by  
15 heating the intermediate substrate (10, 7) before said ink image (X) is deposited thereon.
10. A method according to claim 2, characterized in that the transferred ink image (Z) on the receiving substrate (A) is cured to a dry ink after exposing the upper surface (T) of the transferred ink image (Z) to radiant energy.  
20
11. A method according to claim 8, characterized in that the ink image (X) on the intermediate substrate (10, 7) is completely cured prior to transfer to the receiving substrate (A).
- 25 12. A method according to claim 5, characterized in that the ink source (301) traverses the surface (11) of the intermediate substrate (10) in a direction perpendicular to the rotational direction of the transfer roller (10).
13. A method according to claim 5, characterized in that the ink source (400) is  
30 stationary.

14. A method according to claim 7, characterized in that both the upper surface (T) and lower surface (L) of the ink image (X) on the intermediate substrate (10) are exposed to radiant energy.

5 15. An apparatus for printing images on a receiving substrate (A) comprising:

- a) a print head (50, 60, 301, 401, 9) adapted to form images on a substrate with an ink curable by exposure to radiant energy, characterized by
- b) an intermediate substrate (10, 7) positioned to receive ink images (X) formed by the print head (50, 60, 301, 401, 9) on a surface (11) thereof;
- 10 c) an advancing mechanism (52) for moving the surface (11) of the intermediate substrate (10, 7) relative to the print head (50, 60, 301, 401, 9);
- d) a radiant energy source (51, 151, 37) positioned to expose the ink images (X) on the surface (11) of the intermediate substrate (10, 7) to radiant energy; and
- e) feeding means (52, 3) which is adapted to move the receiving
- 15 substrate (A) so that it contacts and overlaps the ink images (X) on the intermediate substrate (10, 7) in such a manner that the ink image (X) transfers to the receiving substrate (A) and forms a transferred ink image (Z) thereon.

16. An apparatus according to claim 15, characterized by heating means (150, 20 31) for heating the ink image (X) on the intermediate substrate (10, 7) to a temperature above ambient temperature.

17. An apparatus according to claims 15 or 16, characterized by a second radiant energy source (56, 38) positioned so as to expose the transferred ink image (Z) on the 25 receiving substrate (A) to radiant energy.

18. An apparatus according to claim 15, characterized in that the radiant energy source (51, 151, 37) also serves to heat the ink images (X) on the intermediate substrate (10, 7) to a temperature above ambient temperature.

19. An apparatus according to claim 16, characterized in that the heating means comprises thermal resistance heaters (31) positioned beneath the surface (11) of the intermediate substrate (10, 7).

5 20. An apparatus according to claim 15, characterized in that the print head (50, 60) includes a traversing mechanism (305, 306) for moving the print head (301) relative to the intermediate substrate (10) in a direction substantially perpendicular to the movement of the advancing mechanism (52).

10 21. An apparatus according to claim 15, characterized in that the print head (401) is stationary and spans the width of the intermediate substrate (10, 7).

22. An apparatus according to claim 20, characterized by barrier means (25) to shield the print head (50, 60) from radiant energy emitted from the radiant energy source  
15 (51, 151, 37).

23. An apparatus according to claim 15, wherein the intermediate substrate comprises a transfer roller (10), the advancing means (52) rotating the transfer roller (10).

20 24. An apparatus according to claim 15, characterized in that the intermediate substrate comprises a continuous belt or ribbon (7), the advancing means (15, 22) rotating the continuous belt or ribbon (7) through cycles.

25 25. An apparatus according to claim 15, characterized in that the radiant energy source (51, 56, 151, 37, 38) is an ultraviolet light source, a visible light source or an infrared light source.

26. An apparatus according to claim 23, characterized by a cleaning wand (30) for cleaning the surface (11) of the transfer roller (10) before ink images (X) from the print  
30 head (50, 60) are formed thereon.

27. An apparatus according to claim 24, comprising a thermal transfer print head (4) for heating the ink image (X) above ambient temperature and for transferring the ink image (X) from the continuous belt or ribbon (7) to a receiving substrate (A) to form a transferred ink image (7).



Application No: GB 9802357.5  
Claims searched: 1-27

Examiner: Gary Williams  
Date of search: 23 June 1998

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): B6C: CSAD; B6F: FBL, FLX

Int Cl (Ed.6): B41J: 2/17, 2/435, 2/44; B41M: 7/00

Other:

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0604024 A2 (TEKTRONIX) See Fig.1, col.1 lines 30-35	15
X	US 4836102 (FUSION SYSTEMS) See Figs.2-4, col.2 lines 47-57	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.